Renewable and Sustainable Energy Reviews 15 (2011) 2974–2983

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Willingness to pay for renewable energy: Evidence from a contingent valuation survey in Kenya

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ARTICLE INFO

Article history:
Received 19 October 2010
Accepted 2 March 2011

Keywords:
Contingent valuation
Double bounded
Electricity connection
Rural
Willingness to pay (WTP)

ABSTRACT

A modern form of energy, in particular electricity for household use, is an important vehicle in alleviating poverty in developing countries. However, access and costs of connecting to this service for most poor in these countries is inconceivable. Policies promoting electricity connection in rural areas are known to be beneficial in improving the socio-economic and health well-being for households. This paper examines willingness to pay (WTP) for rural electrification connection in Kisumu district, Kenya, using the contingent valuation method (CVM). A nonparametric and a parametric model are employed to estimate WTP values for two electricity products: grid electricity (GE) and photovoltaic (PV) electricity. The results indicate that respondents are willing to pay more for GE services than PV and households favoured monthly connection payments over a lump sum amount. Some of the policies suggested in this paper include: subsidizing the connection costs for both sources of electricity, adjusting the payment periods, and restructuring the market ownership of providing rural electricity services.

Contents

1. Introduction

Since 1973, the Rural Electrification Programme (REP) has been established to enhance rural electrification in Kenya. Recently, several legislations have been proposed to promote electricity generation, transmission and distribution (e.g., the 2006 Energy Act and the 1997 Energy Power Act) with priority geared towards economic and social centres in rural areas. Despite these efforts and the Kenyan government's objective to increase rural electrification, a great proportion of rural households lack access to electricity [1]. Indeed, around 4% of rural areas in Kenya is reported electrified [2]. Clearly, households' limited access to electricity service leads to a debilitating state of economic, environmental, and health conditions. On the other hand, the benefits households derive from a better access to electricity use include lighting, entertainment and running small income generating activities, ecological (air quality and forest protection) and health well-being. As a result, better access to electricity for many households provides a change in welfare when households are able to engage in more income generating and safer activities and when educated communities use lighting and entertainment services.

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1364-0321/$ – see front matter.
doi:10.1016/j.rser.2011.03.016

Acknowledging the shortcoming in electrification for the poor masses in Kenya, the Ministry of Energy (MoE) concurs that a new direction is needed to increase the rate of electricity supply to the rural poor. Rural Electrification Programs in most developing countries are usually catered by grid and off-grid electricity sources. Grid electricity (GE) widely covers heavily populated areas albeit off-grid systems such as photovoltaic (PV) systems and mini-hydros or diesel operated systems cater to relatively less-populated areas. Some perceive electricity from the grid-based sources in competition with PVs, though this is not true as there are divergences between the two sources [3]. Others view PV (solar electricity) as a 'pre-grid' electricity option for rural areas [4]. Nonetheless, PV may appeal to rural households over GE, where the PV is more reliable than GE, as the latter is prone to power outages. Overall, both PV and GE are preferred over petroleum products such as kerosene and liquefied petroleum gas because in the long run these products are highly priced and subject to shortages as they are imported from politically volatile regions in the Middle East.

One of the main obstructions to rural electrification expansion in Kenya is the connection fee for households [3]. To sidestep these limitations, several recommendations have been put forth. Some critics argue in favour of financing schemes (e.g., Sanghvi and Barnes [5]). Others have great sentiment for spreading the connection fee over many years and charging more per unit of electricity consumed (e.g., Barnes and Foley [3]).

The purpose of this study is to examine the expansion of electricity access (grid and off-grid options) by evaluating the uptake of renewable energy electricity among non-electrified households in rural Kenya. Using a contigent valuation survey, we provide new evidence about the demand for renewable electricity connection in a developing country context. Specifically, we estimate and compare WTP to connect to two electricity goods (grid electricity and photovoltaic) using two payment plans (monthly and one-time lump sum). We address the following questions: Do households' attitudes and behaviour vary with electricity products and payment plan to connect to electricity services? What factors affect the household demand for electricity in rural Kenya? Due to the dearth of market information or revealed preference data on these issues, valuing rural electricity services is important for two main ways. First, household WTP for electricity services is paramount to stakeholders in making tariff decisions. Second, estimate of aggregate WTP for electricity services is fundamental to examining the welfare impacts of such services and the viability of these projects in rural areas.

This paper is structured as follows: Section 2 presents a brief review of the contingent valuation literature related to energy studies; Section 3 elaborates on the survey methodology. Section 4 provides the theoretical and econometric framework. Section 5 presents the empirical results, and Section 6 concludes the paper.

2. Methods for valuing energy services

Economic valuation has been widely used, for example in the health, transport and the environment sectors. The use of valuation methods has increased due in part to the number of interest groups, corporations, governments and researchers demanding economic values for non-marketed goods or services. According to the Energy Sector Management Assistance Program (ESMAP) [6], deriving the WTP for improved water and energy services in developing countries using surveys is challenging. Difficulties include unidentified biases, false demand responses and onerous sample selection. These hardships are acknowledged in this study and are described further in the survey methodology section. The National Oceanic and Atmospheric Administration (NOAA) panel guidelines are based on CV studies in the US and developed countries. It is worth noting that developing countries differ from developed countries in the social-economic and political structures, making the NOAA guidelines relatively difficult and costly to implement in the former compared to the latter nations.

The common application of stated preference (SP) method in sub-Saharan Africa has been in areas such as agriculture, tourism and wildlife, with limited studies related to the energy sector. The commonly used SP approach in the energy sector involves choice experiment (CE) as applied by Goett and Hudson [7], Roe et al. [8], Alvarez-Farizo and Hanley [9], Arkesteijn and Oerelemans [10], Bergmann et al. [11], Longo et al. [12], Ladenburg et al. [13], An et al. [14] and Beenstock et al. [15]. In reviewing some of the SP studies, the WTP estimates were significant and varied according to income, age, type of energy sources (green electricity, wind farms and biomass), service attributes, and power outages and/or fluctuations.

While the above mentioned energy studies concentrated primarily in developed countries' energy markets; a limited number of studies have addressed CV in developing countries context in relation to electricity market. As a result, this study is an attempt to measure the economic value of electricity connection in rural areas when household's preferences and attitudes towards electricity connection, when a new directive is introduced by the government in connecting households to electricity services.

In most SP manuals (Champ et al. [16], Bateman et al. [17] and Alberini and Kahn [18]), the need to examine either the quality or quantity of changes as a result of a policy change is emphasized. In this paper, one of the policy changes being examined in relation to electricity connection services is the introduction of payment schedules (one-time lump sum and monthly) to access two electricity sources, namely PV and GE. The analysis is conducted using a parametric and nonparametric estimation framework. Our study is the first to use parametric and nonparametric estimation to address the demand for renewable energy in a developing country perspective.

3. Survey methodology

During the month of August 2007, 200 households with 100% response rate were interviewed by five enumerators in Kisumu district. Kisumu district is the third largest city in Kenya and is located in Nyanza province. This district is one of the 12 districts in Nyanza and was selected because of its political and economic vigour relative to the other districts in Nyanza. Around 13% of Nyanza's total population of 5,051,562 is Kisumu's population, while nearly 53% of the total population in this district lives below the poverty line. The electrification rate in Kisumu rural area is 36% compared to urban areas of around 64% [19]. Table 1 presents some Kisumu's socio-economic and demographic (SED) characteristics relative to the province and national levels.

3.1. Sample design

The sample design was chosen based on cluster listing implemented by Kenya's national census. This cluster sampling framework, known as NASSEP IV,[1] involved the compilation of 1800 clusters on a nation-wide basis, two thirds rural and one third urban. In the case of Kisumu district, 39 clusters were identified under this framework, 15 rural and 24 urban. From this, it can be seen that Kisumu is substantially urbanized. In this regard, 9 of the 15 rural clusters were identified as being electrified. An electrified cluster was defined as one in which there existed at least one electricity transformer in the cluster area and the identification

[1] NASSEP is defined as National Sampling Survey and Evaluation Programme (NASSEP).

Table 1
Socio-economic and demographic characteristics at the district, province and national levels.

	Kisumu district	Province level	National level
Total population 2006	650,846	5,051,562	35,514,542
Rural population 2002 (%)	36.03	87.10	67.20
Urban population 2002 (%)	63.97	9.15	32.80
Annual per capita 2004 (Ksh.)	17,535	12,616	24,836
Electrification cover 1999 (%)	11.62	4.80	13.50
Poor individuals 1999 (%)	47.1	42.1	43.7
Household mean size 1999	4.9	5	5.2

Source: Various (World Bank, Kenya CBS, Kenya Ministry of Communication, Kisumu District Development Plan 2002–2008).

of a cluster as being electrified was attributed by Kenya National Bureau of Statistics (KNBS) officials. Most electricity transformers and lines in rural areas are located in commercial or major trading areas, alongside tarmacked public roads. Most of the clusters selected in this study were located on public or government roads and were accessible by public transport. Moreover, commercial or trading centres of villages were the central point for commencing the process of mapping the sample and for identifying the households to be interviewed. Each cluster was readily identifiable as a distinct entity. Moreover, the process of household identification was facilitated by employing two experienced KNBS enumerators who had worked on previous surveys using the same clusters. Once a chosen cluster was located, it was divided into five zones, one for each enumerator.

Every zone following footpaths or minor roads leading to rural residences was considered to be a random way for selecting the sub-populations. Consequently, a systematic sampling technique was adopted and carried out in the five zones. That is, starting from the transformer, each enumerator selected every third household, to either the left or the right of a footpath or minor road, for the purpose of interviewing. Non-electrified households were easily identified as it became evident that there were no electricity wires attached to the homes in question. In situations where the number of non-electrified households was not sufficient in one zone, the zones were further sub-divided and re-assigned to the enumerators, until the quota of 20 for each zone was reached.

The present condition for non-electrified households (i.e. the status-quo) is the consumption of traditional fuel sources such as wood fuel and charcoal. Nevertheless, the change is the connection of electricity services by PV and GE and an introduction of a policy where varied payment schedules are introduced. GE is transmitted and distributed by KPLC, a public limited company, with the Kenyan government holding 51% of shares in the company.[2] Conversely, PV is dominated by the private sector with limited incentives to market the goods.

3.2. The questionnaire and survey implementation

The survey questionnaire is divided into four main sections. The first section includes introductory 'warm-up' questions aiming at making respondents feel comfortable with the interviewers and the questions. The second section of the questionnaire contains the CV scenario. The third section examines the different fuel sources, uses, and patterns as recommended by the World Bank dossier [20]. The final section includes socio-economic questions which are mostly considered sensitive to interviewees.

The survey was implemented using personal interviews which, in a developing context, are a low cost method in contrast to such methods as mail and telephone surveys. Like many other developing countries, Kenya's mail and telephone infrastructure is limited, poor, and costly. Despite the low cost of personal interviews, there are other administrative costs including those related to the hiring of local enumerators, which increase the total survey costs.

To avoid interviewer bias, the enumerators were well trained and assigned randomly to the respondents. All the 200 respondents were offered questions related to the two types of electricity systems (GE and PV) and the two alternative payments schedules: monthly (for 60 months) and one-time lump sum. The first question was a simple yes or no question "Are you willing to pay amount X to connect to PV electricity or GE?" If the answer was yes (no), another question followed to elicit a maximum (minimum) value. Hence, the respondents identified two amounts that limited their maximum WTP [17].

Also, the study applied two approaches to examine the protest zeros. One was the analysis of upper and lower bid responses against the total yearly or monthly income.[3] The other involved the introduction of an open-ended question after the DBDC questions. The open-ended question asked was "You have answered both questions as "no–no", then how much are you willing to pay?" The protest rates for the goods range from 20% to 38%. A non-response rate of 20–30% is common [21] and therefore the non-response rate is within acceptable limits under which the WTP values can be estimated.

To avoid partial response bias, the sensitive socio-economic questions are relegated in the last section of the questionnaire, as mentioned above. The respondents did not feel uneasy responding all the questions. Thus, partial response bias is less of a concern. At the end of the questionnaire, debriefing questions were included to rate the interviewees' understanding and to obtain comments about the questionnaire. Another common CV bias is hypothetical bias, where the hypothetical WTP deviates from the real WTP. Hypothetical bias occurs when a respondent states that s/he will pay for a good when in real life s/he will not, or s/he will actually pay less when placed in a comparable purchase decision. Hence, to minimise this bias, the hypothetical scenarios were translated into the local language (*Luo*) and the local enumerators were instructed to explain to the respondents the scenarios as actual as possible. For instance, if prospective customer fails to pay for the connection amount as issued by KPLC in a monthly electricity bill, they will be disconnected from the service. Moreover, prior to the actual survey in August 2007, some focus group discussions involving in-depth discussions of prospective respondents were carried out in April 2007. These discussions assisted in identifying local description of the hypothetical scenarios and the survey instrument was tested among participants.

4. Theoretical and econometric framework

The importance of examining the theoretical framework in the context of attitude theory and economic theory is to deter-

[2] In recent years the Government share in the company has decreased to 40.4% [51].

[3] There were less than 5 households with grid electricity (lump) who reported contrary bid amounts to their income and the rest namely grid electricity (monthly), photovoltaic (monthly & lump) did not report such a contradictory way.

Table 2
WTP bids in Kenya Shillings[a] as applied in the Kenya Energy Household Survey (2007).

Sub-groups for bids	GE and PV lump			GE and PV monthly		
	Initial bid (Ksh.)	Upper bid (Ksh.)	Lower bid (Ksh.)	Initial bid (Ksh.)	Upper bid (Ksh.)	Lower bid (Ksh.)
1	34,000	41,000	27,000	800	960	640
2	35,000	42,000	28,000	820	970	660
3	36,000	43,000	29,000	840	1000	680
4	37,000	44,000	30,000	870	1030	700

Source: Survey 2007.
[a] August 2007, US$ 1 was approximately equal to 80 Kenyan Shillings.

mine the decision making process. Nevertheless, understanding this framework may explain how different WTP values are decided by respondents. According to Green and Tunstall [22], preferences and values are the foundation of CV design and the extension of the Fishbein-Ajzen model (a reasoning model which holds that beliefs determine attitudes and attitudes are known to impact the behavioural intentions) with one plausible behavioural intention is WTP. This conceptual framework examining preferences, attitudes, and behaviour is relevant to economic application of random utility theory.

The question format used in this CV study, was the double bounded dichotomous choice (DBDC) in which a closed-ended question consisting of a binary response of a yes or no answer to initial and follow-up questions. In this method, unlike the single bounded question, a yes or no response to the follow-up question, sharpens the WTP estimates [23]. Moreover, the advantage of introducing a follow-up question to a single answer helps reduce the variance of the WTP estimates [24]. A DBDC model is more efficient than a single bounded one, because the former acts like an 'insurance' against poor choice of bid values [25]. Haab and McConnell [26] stated that there are three ways why DBDC is more efficient than the single bounded format. First, the yes–no and no–yes provides a clear bound of WTP, second the 'no–no' and 'yes–yes' estimate efficiency gains, and third the number of responses is substantially increased, especially for larger sample sizes. To avoid initial bid biases, the initial bids were randomly assigned to respondents in the four sub-samples as shown in Table 2.

To estimate WTP, two econometric methods are considered, namely: nonparametric (NPM) and parametric (PM) framework. Each of them shares some advantages and disadvantages. Unlike the parametric, the nonparametric approach-eliminates all fixed assumptions about distribution and functional forms [27] and is computationally more amenable as calculations can be done "on the back of an envelope" [28]. Haab and McConnell [29] stated that NPM framework is a novel and straightforward method allowing one to obtain estimates and standard errors by a hand calculator. NPM estimation has been used in many CV studies (see Kristrom [28], Haab and McConnell [29], Carson et al. [30] and Loureiro et al. [31]). In other cases, nonparametric is mixed with parametric estimation to create semi-parametric estimations [32]. One primary disadvantage of the NPM approach is that it provides minimal economic information [23].

To illustrate the nonparametric method, consider a case where a discrete question is posed to respondents with a statement like: would you be willing to pay an amount c_j?, where c_j is indexed $j = 0, 1 \ldots M$ and $c_j > c_k$ for $j > k$, and $c_0 = 0$. Let p_j be the probability that respondent's WTP denoted by W is in interval c_{j-1} to c_j as:

$$p_j = P(c_{j-1} < W \le c_j) \quad \text{for } j = 1 \ldots M + 1.$$

In most cases respondents are asked c_j for $j = 1$ to M and $c_{M+1} = \infty$ or in another way, the cumulative distribution function (cdf) is presented as:

$F_j = P(W \le c_j)$ for $j = 1 \ldots M + 1$, where $F_{M+1} = 1$ and F_j is the proportion of observed no response.

Then

$$p_j = F_j - F_{j-1} \quad \text{and} \quad F_0 \equiv 0.$$

The Turnbull estimator is derived by treating either the F_j, $j = 1 \ldots M$ or p_j, $j = 1 \ldots M$ as parameters. When the F_j are parameters the likelihood function is written as:

$$L(F;\ N,\ Y) = \sum_{j=1}^{M} [N_j \ln(F_j) + Y_j \ln(1 - F_j)], \tag{1}$$

where N_j is the *number of "no" respondents to* c_j, Y_j is the number of "yes" respondents to c_j, and $(1 - F_M) = p_{M+1}$ is the probability that W is greater than highest finite bid.

Eq. (1) can also be written as:

$$L(p;\ N,\ Y) = \sum_{j=1}^{M} \left[N_j \ln\left(\sum_{i=1}^{j} p_i\right) + Y_j \ln\left(1 - \sum_{i=1}^{j} p_i\right)\right], \tag{2}$$

where in Eq. (1) the $p_j s$ add up to unity, though for the p_js to derive a reliable density function, they must be non-negative and stay within the unit interval.

To obtain a valid estimate of probability density function (pdf) of W from Eq. (2), the p_i must be constrained to be positive and must fall within the unit interval.

This ensures that $p_i > 0$, so long as $N_1 \ne 0$, hence the first order condition for p_i always hold with equality when at least one respondent provides a no-response to c_1.

Deriving the unconstrained first order condition for Eq. (2) and solving for p_1 yield:

$$p_1 = \frac{N_1}{N_1 + Y_1}, \tag{3}$$

and similarly, solving for p_2, we obtain:

$$p_2 = \frac{N_2}{Y_2 + N_2} - p_1,$$

p_2 is positive if $N_2/(Y_2 + N_2) > N_1/(N_1 + Y_1)$ where the responses are monotonically increasing.

In a case where $N_2/(Y_2 + N_2) < N_1/(N_1 + Y_1)$, a non-monotonic response, the unconstrained maximum likelihood estimate of p_2 will be negative. Generally, when p_j is negative, a Kuhn–Tucker solution is to combine the jth and $(j-1)$th cells and re-estimate p_j.

The mean lower bound WTP used in this study, as depicted by Haab and McConnell [29], is given by:

$$E_{LB}(\text{WTP}) = 0 \cdot P(0 < W < c_1) + c_1 P(c_1 \le W \le c_2) + \cdots c_m P(c_m \le W \le c_{m+1}) = \sum_{j=1}^{M+1} c_{j-1} p_j, \tag{4}$$

where $(1 - F_M) = p_{M+1}$.[4]

[4] An upper bound on WTP is similarly defined as $\sum_{j=1}^{M+1} p_j c_j$, though in most instances c_{M+1} is infinite and therefore the upper bound is unbounded. If all individ-

Table 3
Number of total responses in DBDC format.

	No_No	Yes_No	No_Yes	Yes_Yes	Total
Grid electricity lump	163	10	19	8	200
Grid electricity monthly	56	69	34	41	200
Photovoltaic lump	174	5	16	5	200
Photovoltaic monthly	120	24	37	19	200

Source: Survey 2007.

PM distribution, unlike NPM, allows for the inclusion of exogenous variables, such as: income and other socio-economic variables, in the model estimation. The use of these covariates allows assessing the validity and reliability of the CV survey, and confirming the *a priori* expectations and extrapolating estimates from the sample to the general population [26]. Three models commonly estimated to derive willingness to pay from double bounded CV include the bivariate probit model as proposed by Cameron and Quiggin [33], the random effects probit model [34] and the interval-data model, also known as the standard double bounded model i.e. double bounded model (DBM) [25].

The three models differ by the assumptions about the mean and variance of WTP estimates for the initial and subsequent question, and ρ, the coefficient of correlation between the error terms of WTP in the first and second questions.[5] In this study, since the coefficient of correlation was estimated at 0.999 for services and payment types, we apply the interval data logit model. As Alberini [35] forcefully points out, estimates from DBM are preferred to those from BPM when there are small biases and large gains in efficiency when correlation coefficient ρ is close to one. Haab and McConnell [26] showed that the WTP estimates derived from each question are the same for this model i.e. for the *i*th individual the WTP is as shown in Eq. (5).

$$\mathrm{WTP}_{ij} = \mu_j + \varepsilon_{ij}, \quad \text{with } j = 1,\ 2. \tag{5}$$

Following Hanemann et al. [25], the likelihood of four outcomes from the DBDC is π^{yy}, π^{nn}, π^{yn} and π^{ny} with the following likelihoods:

$$\begin{aligned}\pi^{yy}(B_i, B_i^u) &= Pr\,\{B_i \le \max\text{ WTP and } B_i^u \le \max\text{ WTP}\}\\ &= Pr\,\{B_i \le \max\text{ WTP}|B_i^u \le \max\text{ WTP}\}\,Pr\,\{B_i^u \le \max\text{ WTP}\}\,.\\ &= Pr\,\{B_i^u \le \max\text{ WTP}\} = 1 - G(B_i^u;\theta)\end{aligned} \tag{6}$$

In the above outcomes, B_i is the initial bid and when respondents say "yes" to the initial bid the second bid is B_i^u, which is greater than initial bid ($B_i^u > B_i$). Otherwise a "no" response to the initial bid if B_i^d is smaller than initial bid ($B_i^d < B_i$).

Since $B_i^u > B_i$, $Pr\,\{B_i \le \max\text{ WTP}|B_i^u \le \max\text{ WTP}\} \equiv 1$.

Similarly $B_i^d < B_i$, $Pr\,\{B_i^d \le \max\text{ WTP}|B_i \le \max\text{ WTP}\} \equiv 1$.

$$\pi^{nn}(B_i,\ B_i^d) = Pr\,\{B_i \ge \max\text{ WTP and } B_i^d > \max\text{ WTP}\} = G(B_i^d;\theta), \tag{7}$$

$$\pi^{yn}(B_i,\ B_i^u) = Pr\,\{B_i \le \max\text{ WTP} \le B_i^u\} = G(B_i^u;\theta) - G(B_i;\theta), \tag{8}$$

$$\pi^{ny}(B_i, B_i^d) = Pr\,\{B_i \ge \max\text{ WTP} > B_i^d\} = G(B_i;\theta) - G(B_i^d;\theta), \tag{9}$$

where $G(.;\theta)$ is the cumulative density function (cdf) of the individual's true maximum WTP. Here $G(.;\theta)$ is taken to be the logistic distribution with mean zero and standard deviation $\sigma = \pi/\sqrt{3}$.

Thus, the corresponding log likelihood function then becomes:

$$\begin{aligned}\ln L^D(\theta) = \sum_{i=1}^{N}\{&d_i^{yy}\ \ln \pi^{yy}(B_i, B_i^u) + d_i^{nn}\ \ln \pi^{nn}(B_i, B_i^d)\\ &+ d_i^{yn}\ \ln \pi^{yn}(B_i, B_i^u) + d_i^{ny}\ \ln \pi^{ny}(B_i, B_i^d)\},\end{aligned} \tag{10}$$

where d_i^{yy}, d_i^{nn}, d_i^{yn}, and d_i^{ny}, are binary-valued indicator variables.

As shown in Table 3, the frequency distribution of the DBDC responses for the survey shows that the vast majority were "no–no", the exception being the responses for monthly grid electricity, where only approximately a quarter were "no–no".

5. Data results and discussion

Table 4 shows the variable definitions and summary statistics. The main variables used in the analysis include income (incm_shl), educational attainment (heduclev_c), age of respondent (age_c), number of household members (hseresid), interest in starting a business (int_buss_yes) and home ownership (rtoption_own). We also used a set of dummy variables such as unemployment, home business ownership, bank account holding, being head of household and having interest in business. Other explanatory variables such as annoyance levels, gender, marital status, and proportion of fuel costs were excluded from the model, because they were later found to be insignificant or highly correlated.[6]

Table 5 shows the results from the parametric double bounded estimation for the four services namely grid lump sum (GE_lump), grid monthly (GE_mon), photovoltaic lump sum (PV_lump) and photovoltaic monthly (PV_mon), with selected SED variables. The DBM model is evaluated with various SED factors as the explanatory variables. These SED variables or covariates were significant in the analysis, with varied signs and significance levels. A negative (positive) and significant coefficient on these covariates implies that households with the corresponding characteristics are less (more) likely to pay for a specific product. For instance, as shown in Table 5, the coefficients on income and interest in business variables are significant and positive. These results are consistent with economic theory, implying that respondents with higher income and those with an interest in business are more likely to pay more for an electricity programme. Conversely, regressors like age and years of residence are significant and negative. Hence, this indicates that the older the household head and the longer the time in residence the less likely the households are willing to pay for GE or a PV system irrespective of payment type.

Educational attainment has an impact on WTP as expected. This variable is positive and significant for models 1, 2 and 3, the exception being model 4, where the sign was negative but insignificant. Similarly, home ownership is positive and significant in all models except in model 2. Moreover, household size, which refers to

uals respond 'no' to the offered largest bid amount, c_M, then $p_{M+1} = 0$, and the upper bound takes an infinite value.

[5] For more details about the three hypotheses testing methods refer to Hanemann and Kanninen [23].

[6] The author estimated other dummy variables for categorical variables, namely: highest education level, years of residence, income and age, which produced mixed results and were later converted to continuous variables and as shown in Table 5 provided more robust results.

Table 4
Summary of variables used in the models.[a]

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
Incm_shl	Income (natural log)	200	2.1411	0.69863	−0.478	3.989
Heduclev_c	Highest education level	200	8.47	4.08934	0	16
age_c	Age	200	39.03	13.7065	19	78
Yrstay_c	Years of residence	199	27.0905	20.9193	3	50
Hseresid	Household size	200	5.385	2.32244	1	14
Numrms	Number of rooms	195	2.8	1.10108	1	8
Married	Married (dummy)	200	0.675	0.46955	0	1
int_buss_yes	Interest in business (dummy)	196	0.58673	0.49368	0	1
Rtoption_own	Rent option own (dummy)	200	0.825	0.38092	0	1
Sexmale	Sex male (dummy)	200	0.315	0.46568	0	1
unemployed	Unemployed (dummy)	200	0.1	0.30075	0	1
Homebus_yes	Home business (dummy)	198	0.37374	0.48502	0	1
Bnkacc_yes	Bank account (dummy)	198	0.33838	0.47436	0	1
Engfarm_yes	Engage in farming (dummy)	200	0.865	0.34258	0	1
Hsehead_yes	Household head (dummy)	200	0.635	0.48264	0	1
Thrd_pre_yes	Third party presence (dummy)	194	0.37113	0.48436	0	1
anny_yes	Annoyance yes (dummy)	199	0.81407	0.39003	0	1

Source: Survey 2007.
[a] varying sample sizes for the means reflects elimination of 'don't know' and missing responses.

Table 5
Regression results from the parametric double bounded estimation (without protests).[a]

Variable	Model 1 GE_lump	Model 2 GE_monthly	Model 3 PV_lump	Model 4 PV_monthly
Income	0.98**	0.59**	0.91**	0.60**
	(−0.38)	(−0.23)	(−0.44)	(−0.28)
Highest education level	0.16**	0.05	0.23**	0.00
	(−0.07)	(−0.04)	(−0.09)	(−0.05)
Interest in business	2.21***	0.83***	2.73***	0.66*
	(−0.61)	(−0.30)	(−0.88)	(−0.35)
House ownership	1.62**	0.48	1.53*	1.09**
	(−0.75)	(−0.44)	(−0.92)	(−0.53)
Age	−0.02	0.00	−0.06**	−0.02*
	(−0.02)	(−0.01)	(−0.03)	(−0.01)
Years of residence	−0.02	−0.02***	−0.01	−0.01
	(−0.01)	(−0.01)	(−0.01)	(−0.01)
Household size	0.11	0.03	0.11	−0.12
	(−0.11)	(−0.07)	(−0.12)	(−0.08)
Constant	9.19***	−3.55***	12.39***	−2.95***
	(−3.05)	(−0.84)	(−4.21)	(−0.93)
Bid	−4.96***	−6.96***	−6.06***	−5.09***
	(−0.85)	(−0.61)	(−1.23)	(−0.59)
Observations	175	183	158	165
Log-likelihood	−105.68	−243.86	−72.53	−189.32

* $p < 0.1$
** $p < 0.05$
*** $p < 0.01$
[a] Standard errors in parentheses.

Table 6
Comparison between nonparametric and parametric mean WTP values excluding protests (in Kshs).

	Parametric lower bound mean	Nonparametric lower mean
Grid electricity (GE) lump	16,640	7214
Grid electricity (GE) monthly	840	775
Photovoltaic (PV) lump	14,010	5469
Photovoltaic (PV) monthly	660	344

Source: Authors' calculations.

the number of people living in a household, is positive and non-significant at all levels for all the four models.

The two tests used to confirm the validity of the estimation were the *t*-test and the Wald test. The Wald test is generally used in hypothesis testing from unrestricted models only. It was chosen in preference to the likelihood ratio test and Lagrange multiplier test, because it is distribution free and computationally simpler [27]. In all four models, the coefficients were jointly significant at all significance levels using the Wald test.

As shown in Table 6 and consistent with statistical theory and empirical findings by Loureiro et al. [31], mean WTP from NPM is lower than that from PM. This difference may be due to the Turnbull estimator in the NPM framework which calculates lower bound of WTP. For the parametric mean WTP estimates, 95% confidence intervals and standard errors were obtained using the Krinsky and Robb [36] procedure with 5000 replications.[7] Results from both NPM and PM show that respondents were willing to pay more for GE than PV regardless of the payment method.

One way to validate CV studies is to compare the survey WTP estimates with other non-market valuation studies. In this respect, a government-funded survey conducted in 2007 for 1766 households in 31 rural districts revealed a higher WTP for rural

[7] The user-written Stata command -wtpcikr- was used to estimate mean willingness to pay and construct the Krinsky and Robb confidence intervals [52].

Table 7
WTP as percentage of yearly income by income deciles (in Kshs).

Deciles	Mean monthly income (Ksh)/decile	Mean WTP of GE lump as % of annual income	Mean WTP for PV lump as % of annual income	Mean WTP for GE monthly as % of annual income	Mean WTP of PV monthly as % of annual income
1	2692	58	55	31	24
2	4531	35	33	19	14
3	5579	28	26	15	12
4	6676	23	22	13	10
5	7766	20	19	11	8
6	9223	17	16	9	7
7	11,298	14	13	7	6
8	14,154	11	10	6	5
9	16,838	9	9	5	4
10	30,630	5	5	3	2

Source: Authors' calculations.

households. In this survey, most households were willing to pay a minimum of Ksh. 32,500. Results from a nonparametric model using the government-funded survey data indicate that, for a one-off payment, the total WTP is Ksh. 55,542 (US$ 830). This amount is nearly three times more than the annual one-time WTP reported in the Kisumu sample. One reason for this difference can be attributed to the fact that the government survey included 145 localities and around 1776 non-electrified households across the country. Moreover, the government admitted that the survey did not interview all types of rural households in equal measure, but concentrated on rural households' living in densely populated areas and market centres throughout Kenya [37].

The monthly income levels shown by deciles in Table 7 indicate that about 60% of respondents fall under an income level less than Ksh. 10,000 (US$ 150). This figure is comparable to the poverty levels of the district where 53% of Kisumu's total population is living below the poverty line. Regarding a one-off payment method, the WTP as a percentage of yearly income shows the first decile having to pay 58% to 55% of their earnings towards GE and PV electricity, respectively. On the other hand, for those in the highest decile a lump sum payment would cost 5% of their total income for either the GE or PV types. A rule of thumb that sets a budget limit for energy services is 10% of total expenditures or income [38], which is regarded as the ability to pay. For income above the fifth decile, the ability to pay a lump sum payment for connection increases because households would not have to pay more than 20% of their income.

Discounting services or goods to households, as in this case for GE and PV systems, allows for a comparison of the benefits occurring in the present with those in the future. By establishing the differences between present and future benefits, an "indifference factor or equivalence" between paying now or paying at a future time can be examined [39]. The different discount rates were calculated by estimating the NPV of the monthly median and mean WTP values for GE and PV electricity for both one and five year periods and are shown in Table 8.

The minimum implicit discount rate for a five year period is around 35% for PV electricity and a maximum of 46% for GE.[8] Conversely, the implied discount rate for a one year period is at a higher discount rate: for GE 165% and 125% for a PV system. These discounts rates appear to be overestimated for all product and payment options. However, these results are similar to those of other CV studies: Johnson et al. [40] and Kim and Haab [41], where they reported a higher discount rate for short term schedules and a lower discount rate for those that were long term. Moreover, high discount rates have been observed in developing countries, where the individual rate of time preference ranges from 6% to 100%, subject to individual borrowing or lending status [42].

The explanation for the high implied discount variation in the sample relates to the level of impatience or 'time preference', whereby households may possess differing priorities regarding service type and payment options. Generally, it is difficult for decision makers in institutions as well as households to execute decisions, when uncertainty looms at a future time. According to Lopez [43], impatience or myopia is a psychological factor that is associated with near term gratification, where individuals prefer having $1 today than in the future because there is a non-zero probability of not being able to enjoy the future income, owing to some reason, man-made or otherwise and thus the future cost or benefit will not occur. Under these circumstances, households may be impatient to connect immediately to the grid at a higher discount rate rather than delay the event. Also, their perceived uncertainties in relation to present government policies towards electrification may have accounted for this level of impatience.

Again, as evidenced in the focus group discussions, household trust in the service providers is an important element in electricity supply. During these discussions the participants expressed their mistrust towards the government and favoured private providers.[9] Consequently, this mistrust may account for a higher discount rate for the GE system in both time periods, as it is partially provided by the government, in contrast with PV systems. That is to say households prefer payment over one year because they do not trust that the government will honour the payment agreement if the payment period is longer.

6. Policy implication and conclusion

The importance of understanding household demand, behaviour, WTP and ability to pay, is relevant to welfare measures as well as project evaluation. Table 9 depicts the total WTP for a year, for the total non-electrified population in the district. The total WTP values for both GE and PV electricity, for one-time payment, indicate nearly comparable payments. However, the total WTP estimates for GE and PV electricity, for monthly payments, are one-half of the lump sum. Indeed, for GE and PV systems, the total monthly payments for households (in five years) are US$ 32 million and US$ 24 million, respectively.[10] These values are

[8] Nonparametric mean WTP estimates indicate the implied discount (Scenario B over 5 years i.e. 60 months) for grid electricity is 123% and photovoltaic electricity stands at 65%. These two rates are different from the parametric models.

[9] Examples of mistrust regarding electricity provided by the KPLC included issues, such as: bribery (corruption), the monopolistic attitude, poor customer service, incorrect meter readings and delays to services.

[10] The yearly amount for monthly payment is obtained by multiplying each monthly payment for PV electricity and GE by 12 and by the total number of non-electrified rural households (2006) in the district which were approximately 42,079 households (88% of 47,817).

Table 8
Implied discount rate for grid and photovoltaic systems.

	Scenario A (one year)		Scenario B (five years)	
	Grid electricity	Photovoltaic	Grid electricity	Photovoltaic
Mean (%)	165	125	45	35
Median (%)	171	122	46	34

Source: Survey 2007.

Table 9
Annual median WTP for the non-electrified by household level and total rural population of Kisumu district.

Scenario	Annual WTP per household (sample)		Total annual WTP for population (district) in millions	
	Total WTP (Ksh)	Total WTP (US$)[a]	Total WTP (Ksh)	Total WTP (US$)[a]
Grid electricity lump	18,780	235	991	12
Grid electricity monthly	10,080	126	532	7
Photovoltaic lump	17,740	222	936	12
Photovoltaic monthly	7800	98	412	5

Source: Survey 2007.
[a] August 2007, US$ 1 was approximately equal to 80 Kenyan Shillings.

relevant for policy making decisions when governments, administrators, donors and investors need to estimate, at the district level, electrification services to rural households using various payment options.

Valuing access to rural electrification for various payment and product options is related to optimal investment by households and institutions involved in REPs. Despite the high costs of rural electrification, the following proposals presented in this paper are policy recommendation to increase connection for the non-electrified population namely: subsidizing the connection costs, support financial schemes to connect to electricity services, adjusting the appropriate payment period to meet the affordability needs of the target population and restructuring the market ownership and institutions related to REP.

A proposition to subsidize the connection costs for both GE and PV systems, is needed, that is to say, the GoK, through the local authorities, could subsidize a third of the connection cost with the rest being paid by the households. However, this connection subsidization would not cover the wiring and consumption costs, for which end-users are responsible. As shown in Table 10, without subsidy, only the highest two income deciles can afford GE systems, if accepting the 10% rule of thumb, as discussed previously. This figure rises to the four highest deciles when considering a non-subsidized PV system. However, when a subsidy of a third of connection cost is included, the proportion of GE households coming within the 10% affordability benchmark rises to four deciles and perhaps more importantly, regarding PV systems, seven deciles fall within this range. This indicates that subsidizing PV would be a far more effective way of meeting the REP objectives in Kenya.

In other developing countries, subsidization policies vary according to government objectives, with regard to REP targets. For example, in the case of Chile where rural electrification stands at around 80%, the average state subsidy per household was US$ 1080 in 1995, which was later increased to US$ 1510 (1999), owing to the priorities set by the state for maximizing rural electricity coverage [44]. In the case of Kenya, there needs to be a distinction made among various provinces. Regions like Coastal, Western and Eastern provinces are perceived as being poorer and as having certain climatic and geographic conditions that can affect the cost of supply for both grid and off-grid systems. Hence, a sliding scale of subsidies is needed with regard to cross-subsidizing for the different Kenyan regions.

The other proposal involves the financial programmes in place to increase connection of electricity services. Most financial institutions in rural areas cater for salaried rural employees, such as civil servants, teachers and self-employed proprietors. Moreover, for the first-time user wanting to connect to grid-electricity or PV systems, financial schemes through banks or microfinance are unavailable. Also, the high implied discount rates from both PV and GE systems, for all payment types, suggests there is a potential for financial institutions to play a significantly beneficial role in society by granting loans to those wishing to install PV systems or connect to the grid.

Table 10
Comparison of monthly charges for connection at actual and subsidized payment cost for grid electricity (GE) and photovoltaic (PV) systems as % of income.

Monthly income deciles	GE actual connection cost (monthly) inclusive of 50 kWh use charge[a] (%)	PV actual connection cost (monthly)[b] (%)	GE subsidized-connection cost 1/3 off inclusive of 50 kWh consumption charge (monthly) (%)	PV subsidized-connection cost 1/3 off, (monthly) (%)
1	58	39	43	26
2	34	23	26	15
3	28	19	21	12
4	23	16	17	10
5	20	13	15	9
6	17	11	13	8
7	14	9	10	6
8	11	7	8	5
9	9	6	7	4
10	5	3	4	2

Source: Survey 2007.
[a] Monthly market total cost of GE system inclusive of variable cost of consumption of 50 kWh costing Ksh. 300 is Ksh. 1599.33 for 60 months at interest rate of 10%.
[b] Monthly market total cost for a PV system for 60 months at 10% interest rate is Ksh. 1041.11 with zero variable cost.

As a result, there is a need to establish long term schemes to finance initial or upfront costs for acquiring PV systems and grid-electricity.

One approach could be to involve multilateral institutions more in providing revolving funds to the GoK, which they would then give to financial institutions as loans and they in turn would provide unsecured loans to households. However, careful attention will need to be paid to the details as to how to deal with defaults, where customers end up not paying the monthly payments. Indeed, delinquent consumers are difficult to manage and require high administrative costs to monitor. Ledgerwood [45] has suggested that once defaulters have been identified, field staff should follow up arrears payments. If the method fails to work, then some of the following initiatives should be employed: public announcements in the press as to who is a delinquent payer, repossession of assets and erecting of signage outside the borrower's home and charging a defaulter with a crime.

As mentioned earlier, the upfront or connection costs are an impediment to electrification in rural areas. The financial programmes available to connect to electricity services differ among different goods and services. For example, in Kenya, the financial schemes to connect to these services are far better for solar PV systems than for grid-electricity, as monthly instalments by hire purchase systems or banking loans exist. According to World Bank surveys, respondents have indicated their willingness to take medium-term loans to pay for the upfront cost and pay them back through their monthly bills over five years or more [46]. A good example is the case of Bolivia, where the number of new customers doubled when connection cost was spread over five years, despite 25–30 cents per kWh increase on grid-electricity cost [3]. This is unlike Malawi's case, where new customers were charged upfront full cost line extension, (with a 30 year life) which resulted in 2% rural electrification rates.

Market ownership for grid-electricity lies with the KPLC, which controls both the transmission and distribution sides. This one-distributor approach could be modified to accommodate private sector participation and ownership. Kenya has a number of well established independent power producers; however, the transmission and distribution are not privatized, as the KPLC is partially state owned. If privatization was allowed then there would be alternative options for transmission and distribution.

On one hand, charging full cost to customers is beneficial, but on the other hand, these charges can be too high for consumers to afford, hence creating a burden for self-generation in other words, consumers generating their own power. Analyzing international private participation in power projects, an ESMAP paper reported that nearly 70% of private participation in developing countries was concerned with generation activities, whereas electricity transmission stood at 3% and distribution at 14%. This would suggest that potential investors perceive the latter two areas of operation as carrying significant market and commercial risks [47]. However, the government role is important in keeping the various competitive approaches, both on and off grid, at competitive rates. In other words, their role is not only to oversee provincial equity to ensure that electricity prices are on a level playing field but also to minimize the investment risks.

This study points to a need for an alternative model for addressing the REP objectives by offering both grid and off-grid options in lieu of simply concentrating on the former. Part of Kenya's REP strategy could be to set up a rural energy service company to provide electricity for households. Households would then contract the rural energy service companies for on-grid and off-grid electricity services and they could own, maintain, and repair equipment. In other cases, the equipment is owned by the household after a specified payment period. A good example of this system can be found in India, where local electricity retailers such as the independent rural power producers own small businesses or cooperatives and secure credit financing to establish an off-grid system or mini-grid. The latter is achieved by either creating a new distribution system or leasing a sub-station already in existence [6].

Another effective approach has been one in Sri Lanka, where the World Bank/GEF Energy Services and the national utilities established "non-negotiable" power-purchase tariffs and contracts with third-party mini-hydro developers [48]. The introduction of these independent power producers and power purchase agreements, along with concessions, has accelerated the privatization of the markets. In Kenya, various power purchase agreements have been established with the independent power producers at the generation level, but what appears to have played an important role in securing these deals is the involvement of multilateral organizations, that provide credibility to the projects [49].

The roles of the different service providers, namely the public, private, and community-based agencies needed for electrifying households should function in a complementary way and this would create healthy competition among all the protagonists [50]. Moreover, the Kenyan policy makers as well as the producers and distributors should take the opportunity to learn from other developing or emerging markets' REP models, to guide them in revamping their current programme. The government position, in providing long-term subsidies for operating and maintenance costs to entities, should be directed to focus on providing; one-off subsidies to private investors and equity financing or long-term loans to intermediaries in order to help in the financing of rural electrification.

The REP should be a bottom-up approach, where users' needs and preferences determine the electricity policies adopted and in return, policy makers need to formulate regulations that incorporate consumer preferences and to develop, either grid-electricity or decentralized electricity systems, to meet the consumers' needs. In conclusion, the government as a facilitator of the REP, needs to be more transparent and accountable, so as to increase the efficacy of the electricity services, to both current users and potential consumers.

Acknowledgements

We are grateful to Royal Economic Society (RES) for the small expenses budget provided in this study and all households and enumerators in Kisumu district who participated in this study.

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